Doug Mahone
Pacific Gas & Electric Co
Heschong Mahone Group

Duct Tightening

California Building Energy Efficiency Standards
Revisions for July 2003 Adoption

November 5, 2001

Duct Tightening

This document addresses key issues associated with proposed changes to the duct tightening provisions in Title 24. These changes are proposed for consideration in the 2005 update to the Building Energy Efficiency Standards.

Description

The treatment of ducts under nonresidential Title 24 standards has been essentially ignored until the AB970 emergency standards process. At that time, a quick fix to provide a credit similar to that provided for residential duct tightening in the 1998 Standards was introduced into the 2001 Standards for certain duct installations in light commercial buildings. The credit was calculated based upon the assumed leakage levels in new residential ductwork. In fact, field data reported on light commercial duct leakage in California indicates that supply duct leakage levels are considerably higher in light commercial systems, and that the return leakage levels could be comparable. Because of the need for expediency, the enforcement mechanism chosen for tight ducts in light commercial buildings was exactly the same as that for residential ducts, namely HERS raters.

The proposed changes are designed to improve the treatment of duct systems in commercial buildings, updating both the assumptions and impact methodology to reflect conditions encountered in commercial buildings.

Benefits

Energy benefits from duct tightening are estimated to be about 20% of the annual cooling consumption in buildings where duct systems are in unconditioned spaces. Peak demand savings are expected to exceed the energy benefits, since the magnitude of duct losses increases with longer equipment run-times and higher ambient temperatures during summer peak hours. Comfort in buildings with tight ducts is expected to improve, since the HVAC systems will be better able to serve the loads in the space. In systems supplying continuous ventilation air, leaky duct systems can actually contribute to warming the space during the cooling season by

supplying air that is warmer than room temperature. In this case, duct tightening can improve comfort during building ventilation, and increase the likelihood that continuous ventilation will be supplied, thereby increasing average ventilation rates and improving indoor air quality. Use of TDV would enhance the cost effectiveness of this measure, since the maximum benefits occur during periods of higher energy valuation.

Environmental Impact

No negative environmental impacts are anticipated for this measure.

Type of Change

The approach involves making duct tightening part of the reference building, similar to what was done for residences in the 2001 standards. Two options would then be available to the building designer: 1) Require third party verification of duct leakage by an approved provider or 2) Install additional duct insulation and some other thermal feature or features to provide an energy neutral option that would not require a separate inspection. In the second option, the measure would be evaluated a part of a performance-based compliance path, where the impacts of non-compliance are traded off for other improvements in distribution system efficiency. The proposed change does not modify the scope of the standards, since duct tightening was included in the AB 970 proceedings. New calculation procedures to address the impacts of duct tightening will need to be developed, since the techniques used in the AB 970 process were adapted from techniques developed for residential buildings. These calculation procedures do not give full credit to duct tightening in commercial buildings with continuous fan operation, and do not consider the hourly variations in distribution system efficiency necessary for TDV implementation. Changes would apply to the following documents:

- ***Standards*** - to describe the new compliance approach.
- ***ACM*** – to describe the new approach to modeling duct leakage impacts applicable to continuous fan operation and TDV.
- ***Manuals*** – similar to changes to the standards, to describe the new compliance approach.
- ***Compliance forms*** – minor changes to reflect differences in testing and sealing procedures.

Measure Availability and Cost

Equipment and materials to seal duct systems are widely available. Traditional approved materials, such as duct sealing mastic are commonly available. Innovative materials and processes are being introduced to the marketplace by Aeroseal, Inc. Testing techniques and qualified contractors to verify leakage levels are becoming more available due to demand created by the residential duct sealing provisions in the standards and the inclusion of duct sealing in the AB 970 process. The Energy Conservatory is a leading manufacturer of "duct-blaster" test equipment used to field verify duct leakage levels. Training available to HERS providers is applicable to this measure.

The results of several research projects currently underway will be used to develop realistic baseline leakage levels. The tradeoff procedure will evaluate the impacts of reducing leakage from the baseline level to the desired reference building level, and calculate an equivalent duct insulation tradeoff.

Costs to seal and test duct systems can be very reasonable. A resource acquisition study done this year for Southern California Edison demonstrated realistic market costs for testing and sealing large numbers of buildings in a quasi-production mode. Contractors participating in the program were able to test and seal up to 5 systems per day using the Aeroseal process. This translates to a cost of $200 per system at an assumed cost of $1000/day for a duct sealing crew, including materials, vehicle and equipment. Once the systems are properly sealed and tested, ongoing maintenance is not required.

Useful Life, Persistence and Maintenance

Long term data on the persistence of duct sealing technologies does not currently exist. Properly sealed duct systems should maintain their integrity, provided approved materials are used. The introduction of new leakage sites during routine maintenance of equipment or building remodeling is unknown at this time.

Performance Verification

Performance verification at initial installation of the measure is an integral part of the delivery process. Test equipment is installed to verify that target leakage levels have been achieved. Increases in duct leakage levels due to material degradation or introduction of new leakage sites during O&M or remodeling operations will not be addressed by performance verification during initial installation.

Cost Effectiveness

The cost-effectiveness of this measure was already demonstrated under the AB 970 proceedings, using some very conservative assumptions on leakage levels and fan operation. Impacts of duct sealing that include the results of recent research will be developed to improve the cost effectiveness calculations.

Analysis Tools

The choice of analysis tools depends largely on the future direction of performance-based compliance. Currently, DOE-2 does not do an adequate job of modeling duct leakage impacts directly. The AB 970 procedure uses an annual system efficiency multiplier adapted from residential buildings to account for duct leakage effects. The annual efficiency multiplier needs to be overhauled to better represent conditions in commercial buildings. A method to model duct leakage impacts on an hourly basis will be needed to accommodate TDV. Development of hourly procedures depends on the choice of simulation program used for Title 24 compliance.

Relationship to Other Measures

Current initiatives concerning lay-in insulation in commercial buildings will influence the overall market potential of this measure. Duct leakage impacts are greatly reduced when the ductwork is located within the conditioned envelope of the building. Initiatives aimed at ensuring that ductwork is located within the conditioned envelope of the building may make this measure obsolete.

Bibliography and Other Research

A summary of important published research on this topic is as follows:

1. Delp W., Matson N., Tschudy E., Modera M., and Diamond R. “Field Investigation of Duct System Performance in California Light Commercial Buildings.” Lawrence Berkeley National Laboratory report No. 40102.

   This paper discusses field measurements of duct system performance in fifteen systems located in eight northern California buildings. It looks at the thermal analysis of the ducts, from the viewpoint of efficiency and thermal comfort.

2. Jump, D., Walker, I., and Modera, M. “Field Measurements of Efficiency and Duct Retrofit Effectiveness in Residential Forced air Distribution Systems.” ACEEE Summer Study. August 1996

   Field tests were performed on 24 houses in the Sacramento, California area pre- and post-retrofit to determine the potential savings due to duct sealing and insulating the duct system. The reduction in energy consumption due to these measures averaged 18% in this study.

3. Modera, Mark. “Two Favorite Test Methods, By the Book.” *Home Energy Online*. September/October 1993.

   This article presents a comparison of blower door and flow hood methods for determining duct leakage in homes.

4. Modera, M., Dickerhoff, D., Nilssen, O., Duquette, H., and Geyselaers, J. "Residential Field Testing of an Aerosol-Based Technology for Sealing Ductwork." ACEEE. 1996

   This paper describes the results of a field investigation of the performance and practicality of sealing residential duct leaks from the inside by means on a technique based upon injecting a fine aerosol spray into the duct system.

5. Xu, T., Modera, M., and Carrie, R. "Performance Diagnostics of Thermal distribution Systems in Light Commercial Buildings." ACEEE. 2000.

   This paper presents findings from a field performance testing of five thermal distribution systems in four light commercial buildings. The field study included distribution system characterization and short term refrigerant-side monitoring.

6. Modera, M., Xu, T., Feustel, H., Matson, N., Huizenga, C., Baumann, F., Arens, E., and Borgers, T., "Efficient Thermal Energy Distribution in Commercial Buildings - Final Report to the California Institute for Energy Effciency," LBNL-45365, August, 1999.

   This report summarizes the state of research on commercial duct leakage, compares it to residential data. Equations describing the various loss mechanisms are described, and the various assumptions discussed. The ability of DOE-2.1E to model duct losses is discussed in detail.

Other ongoing research relevant to this topic is listed below. Timing of the expected results with respect to this project is also assessed:

Project / Researcher	**Sponsor**	**Description**	**Results Available**
Duct sealing and refrigerant charge testing in exiting small commercial buildings in Southern California. / John Proctor and Mark Modera	SCE	Resource acquisition project will correct charge and seal ductwork in about 250 buildings during the summer of 2001. No monitoring planned but pre/post charge and duct leakage data available.	Yes
LBNL Pier Project Element 4 - Low Energy Cooling. / Mark Modera	CEC	Development of analytical procedures to model the impacts of distribution efficiency improvements. May involve adjustments to overall system efficiency and/or enhancements to EnergyPlus.	Not known
2005 Update to Title 24 / Charles Eley et al.	CEC	Updates to 2005 Title 24 non-residential standards will be studied. Topics include sizing, fan energy, refrigerant charge, T-bar ceilings and computer modeling.	Concurrent
NBI Pier Integrated Energy Systems Productivity & Building Science Program Element 4 - Integrated Design of Small Commercial HVAC Systems / Pete Jacobs - AEC	CEC	Improvements to the installed efficiency of small HVAC systems will be investigated, including duct tightening. Statewide impacts of duct sealing will be developed.	Yes (preliminary)
NBI Pier Integrated Energy Systems Productivity & Building Science Program Element 5 - Integrated Design	CEC	Improvements to insulated ceiling systems will be investigated, including lay-in insulation on suspended ceilings. The impacts of	Yes (preliminary)

of Commercial Building Ceiling Systems / Jon McHugh - HMG		different insulation systems on distribution system efficiency will be investigated.	

Relevant Industry Standards and Organizations

1. ASHRAE Standard 152P - Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems. This is the current standard for residential system testing, and forms the basis for the current residential and non-residential compliance procedure.
2. CHEERS Raters. Certified raters that currently perform duct leakage testing for residential and commercial buildings should be consulted about the practical implications of the proposed changes to the standards
3. NEBB. The National Environmental Balancing Bureau is a trade organization representing businesses providing testing and balancing services. This group represents a key trade ally in the expanded implementation of the proposed changes to the standards.